Aquafeeds of the future

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Aquaculture = protein conversion

1. Most commercial aquaculture species are carnivorous species, why? → Better taste!
2. Fish and shrimp are not very good in taking energy from starch (except tilapia, carp, pangasius, …)
3. Fish feeds are high in protein (30-50 %)
4. Protein conversion is low (<20 %)
5. A lot of the proteins come from the sea (fishmeal, shrimp meal, squid meal, krill)
6. FIFO ratio for marketing
7. All usable fish is sold for human consumption, simply because sales value is higher
Protein sources in aquafeeds

Fishmeal supply limited and expensive.
alternatives:
• Unutilized fish sources (by-catch/by-products)
• Soybean and other vegetable proteins: processing to concentrate the proteins/make them more digestible
• By-products from Biofuel production (DDGS, Canola meal,…)
• Entoproteins: Silkworm pupae meal, worm meal, other insect meals
• Processed Animal Proteins: Blood meal, meat meal, feather meal, hydrolyzed proteins
• Single Cell Proteins (bacteria, yeast, funghi, algae)
• …….
What influences results of feed on the farm?

• Ingredients used
• Formulation
• Production
• Storage and logistics
• Feeding management on the farm
Choosing ingredients

1. Use available ingredients on the market
2. Discuss with suppliers/producers to adapt the process of production to meet the specific requirements for shrimp
3. Produce ingredients
4. Use available local (moist) ingredients and waste products such as fish by-products, by-catch, brewery spent grain and yeast, activated sludge from food processing. Moist ingredients can have multiple functions: valuable nutrients, attractability and binding/gelling (Hygiene!)
Ingredient sources

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What is a protein?

- Chain of amino acids
- Secondary links between amino acids determines the form and functionality
What is a crude protein? 
(Kjeldahl method)

• An easy method to estimate protein content
• This analysis destroys the proteins in the sample and then measures Nitrogen.
• Assumption is that Protein is N-content * 6,25, because protein contains an average of 16% Nitrogen.
• Some other molecules contain nitrogen and are measured as crude protein: nucleic acids, some vitamins, chitin, TVN are always present in raw materials.
• False proteins to cheat: ureaformaldehyde (146%), melamine (416%), ammoniumnitrate (219%)
Quality of proteins in aquafeeds

- Protein level
- Amino acid level (balanced according to requirements)
- Digestibility of protein sources


Protein digestibility

pH stat method for *Litopenaeus vannamei* for degree of hydrolysis (DH%) (Daniel Lemos, Brasil)

Is the best method to check digestibility of proteins (ingredients/complete feeds)

Can predict which feed will give the best growth

- *Enzymes*: crude extracts obtained from shrimp hepatopancreas;
- Feed/ingredient protein water homogenated

**Digestive Capacity**

pH-stat reaction system
Animal vs Vegetable proteins

• Animal proteins (fish meal, squid and shrimp meal, PAP, come from an aqueous environment)
• Most vegetable protein sources come from oilseeds (soybean meal, canola, sunflower, peanut and cottonseed meal) and are less water-soluble
Protein forms

• Vital proteins (non coagulated)
• Functional proteins (hormones, enzymes, immunoglobulin, anti-nutritional factors)
• Coagulated proteins
• Denatured proteins (a functional proteins that has lost its function)

Examples:
• Positive: anti-trypsin in Soybean meal is denatured by heating
• Negative: enzymes become inactive after heating
Hydrolyzed vs soluble proteins

Solubles proteins (solubles) are proteins that are removed from a raw material after cooking and pressing (f.e. Fish solubles). These proteins were present in the raw material as water soluble proteins, and because of that, stay in the water fraction after pressing. They are either short chained proteins (amino acids and peptides) or proteins with a high proportion of water soluble amino acids.
Hydrolyzed vs soluble proteins

Hydrolyzed proteins (hydrolysates) are proteins that are treated with enzymes to increase digestibility. They also contain long and short chained proteins (average length will depend on time of digestion). But amino acid composition remains the same as the original raw material.

Heating hydrolyzed and soluble proteins does not change affect their digestibility.

Both are good attractants and palatants for aquafeeds.

They are important sources of proteins in animals with poor digestive systems (larvae, shrimp, piglets).
Vital vs coagulated proteins

Example of vital proteins: wheat gluten and egg white

When heated, the form changes and they bind with other raw materials. However, once changed they lose their binding capacity.

During spray drying or flashdrying, the product is not heated enough to change the protein structure. It remains vital.

Meat proteins (fish or animal) have a similar binding capacity.

When fresh, ground fish is added to aquafeeds, it improves the binding of the pellets, because it binds during extrusion or pelleting.
Coagulation of fish proteins

During the production of fish meal, the fish by-product is heated to reduce the water binding, so that water can be pressed out as much as possible (to reduce heating cost)

LT fish meal (dried at lower temperature) has more binding capacity
Flash dried fish meal still has all binding capacity
Production of aquafeeds

During the production of aquafeeds, whether it is pelleting or extrusion, the proteins are heated. The proteins which were still vital will act as binder to hold the feed pellets together.
Soybean protein concentrate

Soy Protein concentrate / blend with hydrolyzed protein (Hamlet Protein) as alternative protein source for shrimp

Figure 2: Average weight of shrimp in second experiment
Shrimp feed without marine proteins

Ureumformaldehyde is a fantastic binder, but it adds Nitrogen to the feed which is not protein. It also decreases the protein digestibility. Wheat gluten and Gelatin are nutritional binders.

<table>
<thead>
<tr>
<th>Diet</th>
<th>WG</th>
<th>PBP</th>
<th>UF</th>
<th>No FM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average growth (g/week)</td>
<td>1,565</td>
<td>1,595</td>
<td>1,550</td>
<td>1,629</td>
</tr>
<tr>
<td>FCR</td>
<td>1.81</td>
<td>1.60</td>
<td>1.66</td>
<td>1.44</td>
</tr>
<tr>
<td>Survival</td>
<td>77%</td>
<td>90%</td>
<td>92%</td>
<td>83%</td>
</tr>
</tbody>
</table>
Production

Technology for on farm production

• Small Pelleting machine (<1000 kg per hour)
• Cold extrusion and spheronization
• Soft extrusion
Cold Extrusion & Spheronization

1. Intake
2. Grinding
3. Mixing
4. Cold Extrusion
5. Spheronization
6. Drying
7. Sieving
1. Intake
2. Grinding of dry ingredients
3. Grinding of wet materials (trash fish, slaughterhouse by-products, brewery by-products, …)
4. First mixing of dry materials and subsequent addition of liquids or wet raw materials. You need a special mixer for wet materials, but it can be a concrete mixer for example
Soft Extrusion

1. Soft Extrusion (T<80° C)
2. Postconditioning (coagulation of proteins, gelatinization of starch)
3. Drying
Formulation

1. In the formula, we need **place** for binders (starch). This limits the flexibility for nutrients. This also depends on the production method.
2. Non coagulated proteins, like minced fish has good binding capacity.
Formulation
On farm production enables to formulate feeds according to the conditions on the farm

1. Adapt formula to size of the shrimp
2. Adapt formula to differences in temperature and salinity
3. Include anti-stress nutrients in periods of stress (disease, low temperature, water exchange)
4. Include carotenoids (astaxanthin) to influence the colour of the shrimp
<table>
<thead>
<tr>
<th>Pelleting</th>
<th>Extrusion</th>
<th>Cold and soft extrusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower investment</td>
<td>Higher cost of investment, energy and spare parts</td>
<td>Lower investment</td>
</tr>
<tr>
<td>Fine grinding necessary for good water stability, plus postconditioning</td>
<td>Good water stability, less need for fine grinding. Harder pellets: better uniformity for crumbling and less dust. Extra investment for density control Possibility to produce small starter feeds</td>
<td>Good water stability, less need for fine grinding. Possibility to produce small starter feeds</td>
</tr>
<tr>
<td>Limited flexibility in formulation, application of binders</td>
<td>Flexibility in formulation (less starch, more fibers), lower raw material cost (less binding materials) Possibility to use moist raw materials</td>
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### Shrimp feed pellets after 1 h in water

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<th>Extrusion</th>
<th>Cold extrusion</th>
<th>Soft extrusion</th>
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![Image of shrimp feed pellets after 1 h in water](image-url)
Farming system

Modified Extensive, Semi-Intensive, Intensive
Natural production of the pond: algal blooms
Salinity of the water
Zero-exchange farming with bacterial flocs
Intensive farming with bioflocs

No water exchange during culture
Isolated building
Recuperation of nutrients through bioflocs
P. vannamei of 30-35 g
Bioflocs – what are they?

A biofloc is an association of detritus with micro-and larger-sized organisms (bacteria, phytoplankton, zooplankton, fibrous material and others), which have a symbiotic action to take up nutrients from water.

Phytoplankton:
- algae

Zooplankton:
- protozoa (ciliates, filamentous bacteria)
- micro-invertebrates (nematodes, rotifers, copepods)
Bioflocs – Influence on Growth

C100: 100% feed
C80: 80% feed
C60: 60% feed
+BF: bioflocs in water

**growth of L. vannamei**

- **C100**
- **C80**
- **C60**
- **C60+BF**
- **C80+BF**

**Day 0**
**Day 14**
**Day 47**
**growth**
Natural production

Based on autotrophic algae (sunlight)
Or heterotrophic bacteria (bioflocs – aeration)

Feed source of zooplankton -> feed for fish and shrimp
Recycling of faeces -> improved FCR, less treatment cost
Future of aquaculture?

Efficient feeds (digestible, balanced)
Sustainable raw materials:
1. processed by-products from raw materials which would be wasted (fishmeal from fish processing, animal proteins from slaughterhouses, DDGS and oilseed meals
2. grown on waste products (insects, bacterial proteins)

Efficient species
Low FCR, high protein conversion
Utilisation of natural production
Thank you!